INSECT FOOD OF FRESH-WATER FISHES

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DOMINION ENTOMOLOGIST

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Its Economic Importance in Relation to Fish Culture and the Conservation of Fresh-water Fish

BY

DR. C. GORDON HEWITT

Dominion Entomologist

ON first thought and without reflection, it may appear strange that an entomologist should have any advice or recommendations of practical value to offer on the subject of fisheries. In regard to the problems relating to insect pests, he is able to assist the farmer, the fruit grower, the forester, the medical officer and sanitarian, the housewife and others who, at some point in their daily occupations, encounter injurious insects; but in what manner, it may be asked, can the study of insects and its application have any bearing on the various problems affecting fish culture, such as the depletion, restocking and general conservation of our fresh-water fish supplies?

If I were preaching you a sermon and offering spiritual in addition to scientific guidance, I should choose as my text, and direct your attention to a passage of the eighth chapter of St. Luke where the parable of the sower is described. We read, as you may remember, that a sower went out to sow his seed. Some of the seed fell by the wayside, some upon rock and some among thorns; but all this seed failed to grow. Some, however, fell on good ground and bare fruit an hundred fold. "He that hath ears to hear, let him hear," the parable concludes.

I wish to call your attention to an aspect of fish culture and conservation which has been entirely overlooked in Canada, but it is one which is of such fundamental importance that we cannot afford to neglect it, a statement to which I trust you will agree. This aspect to which I refer is the consideration of the bearing which the food of our fresh-water fishes has on their conservation. By the conservation of our fresh-water fishes, I mean, of course, their care and utilization to that extent which will enable us to make the gratest use of them to the advantage of the people generally.

Extent of Fresh-water Fisheries

In speaking of fisheries and in discussing fishery questions, reference is usually made to sea fisheries. In most cases, our fresh-water fishes have suffered a neglect which their importance and potential value do not in the least justify. We

should not forget, indeed we cannot forget if we will only glance at the map of Canada, the enormous extent of the fresh-water fisheries of this country. When it is realized that about 220,000 square miles of our territory consists of fresh water and when it is understood that the only product of this valuable resource is fish, the significance of the fresh-water fisheries to our people, especially to the millions who will live at considerable distances from the sea fisheries, will be more clearly appreciated. Consider Nova Scotia: about one-sixth of the area of this province consists of fresh water. It is estimated* that at least 7,000,000 lbs. of fresh-water fish of all kinds are taken annually in the provinces of Saskatchewan and Alberta in which at least 40,000 square miles of lakes and rivers are open to fishery enterprise. The value of the fresh-water fisheries of Manitoba for the year ending March 31st, 1912, was $1,113,486.

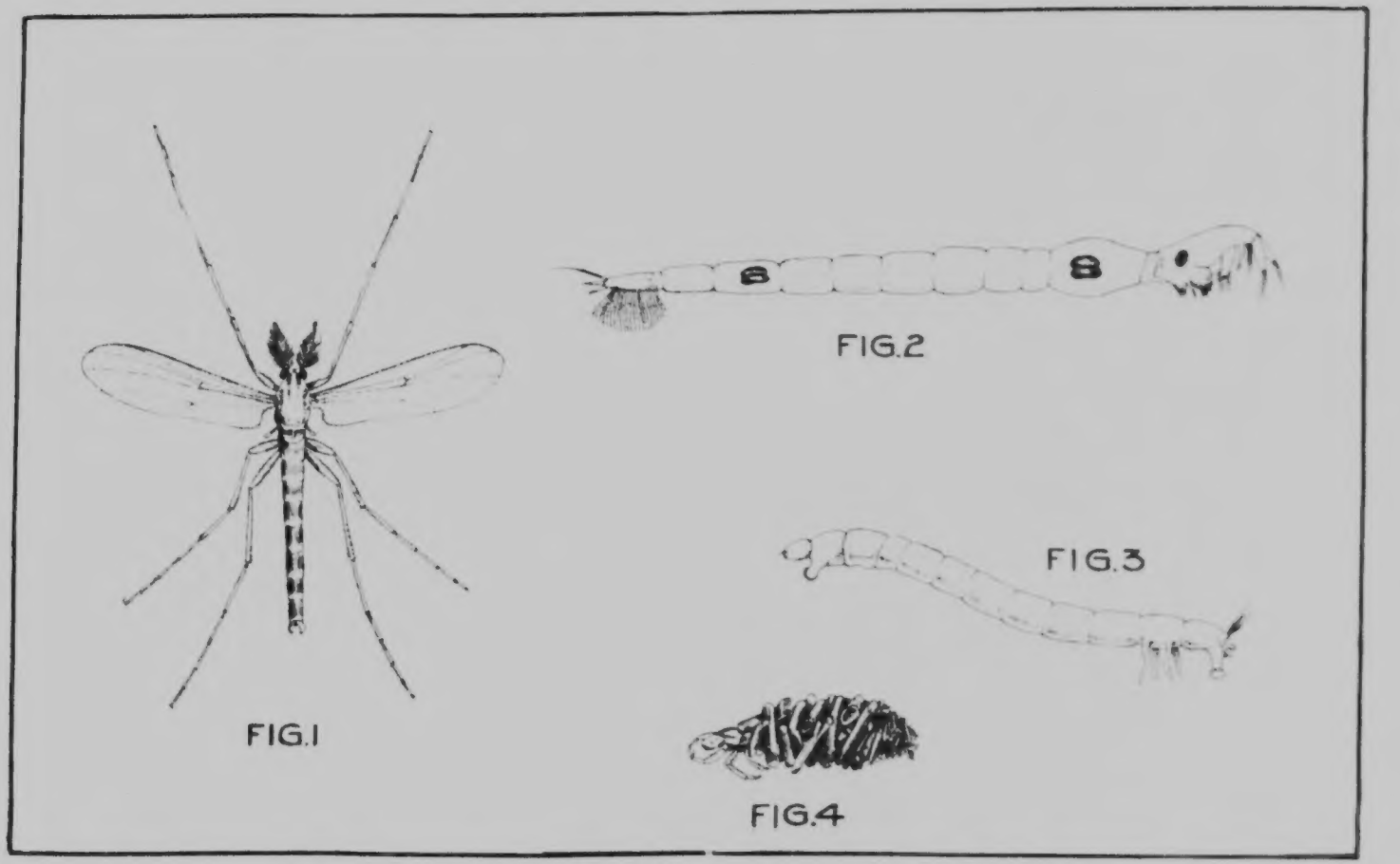
Their Importance

The foregoing statements will bring to your minds the extent and value of the resource of which I am speaking. Is it not important then that we should seek to apply the correct principles of conservation, the greatest use with the least waste, to this inestimable resource? Not only is it important to the inhabitants of the cities that, in these days of rising prices and increasing cost of living and of food, we should make the best use of so valuable a source of food supply, but it is to my mind of still greater importance to the settler. We are bringing thousands of homeseekers annually into our western provinces. Many of these are compelled to settle in localities where meat is scarce and difficult to obtain. Is it not most desirable and important then that we should endeavour to make the nearby supply of fresh-water fishes as productive as possible for the benefit of the local farmer as well as of the fisherman who supplies the city markets?

Aquatic Insect Life

With these facts in our minds concerning the extent and significance of our fresh-water fisheries, let us consider what bearing the subject of the insect food of fresh-water fishes has upon their conservation. Those of my audience and others who are disciples of Isaac Walton, by using insects as their snares, tacitly acknowledge the importance of insect life in the economy of the life of a fresh-water fish such as the trout. The employment of imitation and real insects and their larvæ as bait for fishes is an acknowledgement by the fisherman of the fact that insects are the favoured food of fishes. The chief food of most of the fresh-water fishes is either

* *Report of Dominion, Alberta and Saskatchewan Fisheries Commission* (1912), Part II, p. 6.



FOOD OF FRESH-WATER FISH (TROUT)

Fig. 1.—*Chironomous*: Adult Fly, Male. Fig. 2.—*Corethra* larva ('Phantom larva'). Fig. 3.—*Chironomus* larva
Fig. 4.—*Trichopterid* larva in protective case ('Caddis worm').

directly or indirectly fresh-water insect life; I say indirectly because the larger fish may feed on smaller fish which, in their turn, feed upon the insect life. This reminds me of the cycle which I learnt when as a student of zoology I was studying marine zoology in the Irish sea, indicating how man indirectly feeds upon mud. Mud forms the food of diatoms, which, in turn, are eaten by small marine molluses and crustacea, and upon these the fishes great and small feed, both directly and indirectly; finally man eats the fishes. Thus nutrition links up the chain of organic life and we see how dependent we and other forms of life are on lower or intermediate forms.

Fresh-water insects are chiefly confined to the shallower portions of fresh water. Here we find the larval stages of May-flies, caddis flies, dragon-flies, stone-flies and water-beetles, etc. They are comparatively soft-bodied and are readily eaten by fishes, both young and old. In the deeper waters, the species differ. Here the larvæ of the Chironomid gnats may be found usually in the mud. Some of these Chironomid larvæ have been called ' blood-worms ' on account of their red colour. The free swimming colourless larvæ, known as ' Phantom larvæ,' of the *Corethra* gnats are found at various depths. The majority of these insect larvæ show various modifications of structure and function which enable them to lead the aquatic life to which they have become adapted. Except in the case of water-beetles and certain water-bugs, they cannot breathe air and so their respiratory apparatus has been modified in such a manner as to enable them, like fishes, to breathe by means of gills. Some are provided with rows of leaf-like gills, others with filamentous gills; the bodies of some are flattened and they cling to stones, others such as the *Trichopterid* larvæ or ' caddis worms ' shelter their soft, and to the fish, succulent bodies in protective cases of varied and amazing design and construction. The assumption of an aquatic life has led to the development of extraordinary methods of feeding, respiration and protection.

All aquatic insects are by no means useful in relation to fish culture. Certain of them on account of their carnivorous habits are positively inimical. The fierce larvæ of the *Dytiscid* water-beetles with their claw-like sucking jaws dearly love a juicy young fish, and certain of the water-bugs will not hesitate to attack young fishes several times their own size. When they do not prey upon the fishes themselves they devour their more defenceless insect congeners.

Insect Food of Fish

The extent to which fresh-water fishes feed upon aquatic insect life will be apparent to any fisherman possessing a little knowledge of insects, if he will only examine the contents of the stomachs of such fish as the trout. In this connection,

I may call your attention to the results of an examination and analysis of the stomachs of twenty-five brook trout which was made in New York state by Prof. James G. Needham* who, more than any other investigator, has endeavoured, and with considerable success, to bring about a truer conception of the importance of the subject of my address. These trout were obtained from a pond controlled by the Adirondack hatchery. With the exception of two hundred and fifty small crustacea known as 'water fleas' (*Daphnidae*) devoured by one specimen, a few trout scales and one small fresh-water mussel, the entire food of the twenty-five specimens of brook trout consisted of insect life, and almost wholly consisted of the larval and pupal stages. The total number of insects found in order of their abundance was as follows: 2,906 *Chironomus*, 156 *Corethra* ('the phantom larva'), 14 trichopter larvæ ('caddis worms'), 2 dragon-fly nymphs (*Aeschna constricta*), 7 May-fly nymphs (*Callibatis*), 8 water mites (*Atax crassipes*). This gave an average for each trout of the following: 116.24 *Chironomus*, 6.24 *Corethra*, 10 *Daphnids*, .56 caddis larvæ, .32 water mites, .28 May-fly nymphs and .08 dragon-fly nymphs. The first three species, namely, the *Chironomus* larvæ, the *Corethra* larvæ and the caddis fly larvæ formed the chief food of the trout.

Professor S. A. Forbes, in his study of fishes of Illinois† has pointed out the importance of these insect larvæ as fish food. He says, "Among aquatic insects, minute dipterous larvæ, belonging mostly to *Chironomus*, *Corethra* and allied genera, are of remarkable importance, making, in fact, nearly one tenth of the food of all the fishes studied." Further in his report‡ on the aquatic invertebrate fauna of the Yellowstone National park (quoted by Needham), he again refers to the importance of *Chironomus* and other fly (dipterous) larvæ. He records the following observations indicating the importance of these larvæ to young fish: "The pond was swarming with mountain trout (*Salmo mykiss*) a few of which I dissected for a determination of their food. One of these, an inch and a half in length, had eaten *Chironomus* larvæ and imagos chiefly, the remainder of its latest meal consisting of other insect larvæ, not in condition to identify, and the Entomostrachan (*Polyphemus pediculus*). A second, an inch and a quarter long, had also fed on *Chironomus* in its various stages of larva, pupa and imago, but had made about a third of its meal of Entomostracha. Another, still smaller (.92 of an inch long), taken from the open lake among the

* Aquatic Insects of New York State, Part II. Food of Brook Trout in Bone Pond. *Bull. 68, N. Y. State Museum* (1903), pp. 204-217.

† Ill. State Lab., *Nat. Hist. Bull. No. 2*, p. 483.

‡ U. S. Fish Comm., *Bull. XI*, pp. 207-256.

small weeds growing on a flat, muddy rock, had filled itself with *Chironomus* pupæ only, as had still another of the same size. A third specimen from this situation had eaten more larvæ of *Simulium** than of *Chironomus* and a fourth had also eaten *Simulium* larva and another dipterous larvæ unknown to me. I may add here that other young trout, in a small swift rivulet near the Lake hotel were feeding continuously August 9, on floating winged insects, mostly, if not all, *Chironomus* and smaller gnat like forms." All the foregoing observations indicate what an important part in the food of the trout the larvæ of a single kind of insect such as *Chironomus*, which live chiefly in the deeper waters in the soft, silt-like mud and decayed vegetable matter at the bottom, constitute.

Interdependence of Food Factors

Not only are the fresh-water fishes dependent to the extent to which I have referred upon insect life for their subsistence, but directly and indirectly, as is the existence of all aquatic life, on many conditions and factors existing in the water. They are affected by the physical and chemical conditions of the water. These conditions very directly affect the food of the fishes. Not only the insects themselves, but also the lower forms of life upon which they subsist, are dependent upon the physical and chemical factors and the nature of their environment. Certain insects cannot live where there is an absence of shore vegetation. In fact, the presence of aquatic plant life is essential to the existence of the majority of the insect larvæ frequenting, as most of them do, the shallower littoral regions. These facts, relative to the intimate dependence of the whole chain of organic aquatic life, of fishes, of insects, and of the lower forms of animal and vegetable life, in which the higher forms feeding upon the lower forms depend upon their presence, and, therefore, upon the factors governing such presence, serve to indicate the complexity of this problem of the food of fishes.

Fish Life and Available Food

In view of the foregoing statements and observations, it would almost seem an act of presumption if any great stress were laid upon the fact that fish life depends upon the nature and quantity of the available food, assuming the other factors to be favourable. Yet if you will only reflect for a few moments upon the methods we are employing in regard to fish culture, concerning which further reference will be made later, does not the underlying principle of the present methods and its inherent faith resemble those of the small boy who attempts to keep gold fish in a bowl of pure water?

* The well known Black Fly whose larvae live in running water attached to stones.

In modern agriculture, we can perform deeds that our forefathers would have considered impossible in the way of growing crops where, under ordinary conditions, such crops would not grow. But would any intelligent farmer sow grain or other crops, or fruit grower plant fruit trees on barren rocks or in soil devoid of plant food? He would certainly not be guilty of such foolishness or waste. On the contrary, he would supply the necessary plant food to the soil before sowing his seed. The re-stocking of fresh-water with fish is a precisely similar matter. Unless it is known that sufficient insect life is available, and that it is of the right kind to supply the needs of the fishes introduced, the re-stocking of fresh waters is a game of chance played with heavy odds against success. If fish life does not exist in a fresh-water area, and unless it is known with certainty that the causes of its absence are not natural causes, it would appear to be a positive waste to attempt re-stocking without, at the same time, supplying the necessary food or in other ways correctly adjusting the natural factors. Some people, like the small boy, have the idea that all that fishes require is water. Given a pond or lake or a stream, all you have to do is to turn in a few thousand eggs or fry and a beneficent providence will accomplish the rest.

Depletion and its Causes

Before considering this question of the re-stocking and introducing of fresh-water fish in relation to available food supplies, it is necessary to call your attention briefly to the causes of depletion. We learn* that in the provinces of Alberta and Saskatchewan the causes of depletion are eight, namely, over-fishing, illegal fishing (dynamite, nets, etc.) infraction of irrigation regulations, improper close seasons, lack of fishery officers to enforce regulations, sewage and other pollutions, drought and fishing through the ice. I would add at least one other cause, namely, the absence of available food, which cause would surely rank high in importance in some of our fresh waters. The causes of depletion and the absence of fish in fresh waters, may, I think, be divided into two main groups, which I would call artificial and natural. The first group of artificial causes would include over-fishing, illegal and out-of-season fishing, and sewage pollution; the second group of natural causes would be lack of food and physical and chemical changes in the water, and drought. The artificial causes have been produced by man, and, with determination, could be rectified by man. Some of the natural causes such as the available food supply, if that is the cause of the absence of fish, can also be attended to if the problem is approached in the right manner. De-

* *Report of Dominion, Alberta and Saskatchewan Fisheries Commission* (1912), Part I, pp. 43-44.

pletion is a more serious question in fresh waters than in the sea. The sea, by its enormous extent, permits migration; fished-out areas can be re-stocked by natural means. This, as a rule, is not the case in fresh waters. The areas are limited, there can be no such immigration of fresh supplies as in the case of the sea. If you take out more fish than are being produced or sustained, gradual depletion will follow. Further, fresh-water fishes are less prolific than sea fishes and therefore their rate of reproduction is not the same. As you cannot, for these reasons, rely on nature to replace the fresh-water fishes to the extent that the sea fishes are replaced, it makes it increasingly important to give the closest attention to the study of those means which are responsible for their life and growth, and of these means all will agree that food is the most important. Of this food, insect life forms the preponderating element.

Re-stocking Fresh Waters

The importance of this question of the available food supply is made increasingly evident when we study the extent to which the re-stocking of great waters and the introduction of new species into new waters already takes place in Canada. For a number of years the Department of Marine and Fisheries has been carrying on work of this nature on a large scale, in addition to the similar work undertaken by numerous fishing and game clubs. Of the latter, we have no complete record, but the statistics of the Department of Marine and Fisheries for the year ending March 31st, 1912, are available and I will quote from these. The fish fry distributed in 1911 consisted (exclusive of salmon which I am not considering in this connection) of various species of trout and also of whitefish and pickerel. Altogether, 332,278,000 fry of these species were distributed. The following list and figures will give you an idea of the nature and extent of the distribution:

From the hatchery at Bedford, N.S., 105,000 fry of speckled trout were distributed in twenty lakes and rivers.

From the hatchery at Lac Tremblant, Que., 48,000 fry of speckled trout and 940,000 fry of salmon trout were distributed in eighteen different lakes.

From the hatchery at St. Alexis, Que., 600,000 fry of speckled, rainbow and grey trout were distributed in fifteen lakes.

From the hatchery at lake Lester, Que., 587,000 yearlings, fingerlings, and fry of grey and salmon trout were distributed in nine lakes.

From the hatchery at Magog, Que., 1,103,000 fry of grey, speckled and salmon were distributed in eighteen lakes and brooks.

In view of what we know as to the requirements of fishes in the way of food, the question naturally arises whether, in the above distribution, the available insect food was sufficient and of the right kind. Are we certain that the species of trout placed in a certain lake would find the right kind of food there and sufficient quantity of that food?

The Problem Stated

This brings me to the chief point of my address, which is, that in order to carry out with the greatest measure of success the re-stocking with fish of waters which have been depleted, or the introduction of new species of fish into new waters, we must have information as to the available food for those fishes which are being re-introduced or introduced for the first time. The case of the farmer again crops up; no intelligent farmer would sow the seed of a crop on soil not containing the plant food necessary to the growth and fruition of such a crop. To bring forth a hundred-fold, the seed must fall on good ground. To ensure success in the introduction of fish fry, they must be introduced into waters in which it is known that food of the right kind and in sufficient quantity is present. If the farmer, wishing to sow his seed, finds the soil poor in nitrogen or some other necessary plant food, what does he do? Everyone knows he sows a crop such as clover, that will give the soil the necessary nitrogen, or, by many of the known methods, he supplies the deficiency, whatever it may be. In fresh-water fishery work the same methods should be followed. Associated with the fish hatchery there should be, if it is found necessary, an insect hatchery. I have no hesitation in predicting that when, in fishery work, a stage of advancement equivalent to the present state of advancement in agriculture is reached, we shall have the cultivation of the food of the fishes carried on in conjunction with the hatching and introduction of the fry. Prof. Needham, to whom I have already referred, has shown that the artificial culture of many of the insects constituting the food of fishes is practicable.

Fish Farming

The culture of the insect food of fishes brings me to the concluding section of my address and that is the possibilities which lie in the idea of fish farming. To many people this will be a new idea, but I can assure you it is not; on the contrary, it is very successfully carried out in Europe. The people in this country, however, have not yet realized the inherent possibilities of this form of pisciculture. There are many farmers throughout Canada who have farms, parts of which are too low-lying and wet to drain, and, in consequence, such areas lie unproductive; and yet, if the farmers only realized the significance of the facts which I have been endeavouring to lay before you, they could make such useless and otherwise

unproductive areas produce a crop as valuable as the crops produced by the best land on their farms, perhaps more valuable; that crop would be fish. If, in such low-lying wet lands, dykes and ponds were cut, some of the ponds serving as fish hatcheries, others as insect hatcheries, fish could be farmed as easily as poultry. With such fish ponds the farmer could supply the market, supply his family or afford fishing enthusiasts all the sport their hearts might desire, and, by these means, reap a valuable harvest from land which could not be utilized in any other way. Fish could be raised in localities where they were naturally scarce. That, also, is conservation,—the making of waste areas productive.

Need for Investigation

Before the ideas which I have but briefly outlined can be carried out, there is required a large amount of work of an investigatory nature, and it is in this regard that the Commission should help to mould public opinion. Having studied this question of aquatic insects and their distribution some years ago in various fresh waters in England, I can say that no one realizes more fully than I, the extent and complexity of the problems which I have raised; but that is no excuse for doing nothing. Is it not a matter of surprise that our 220,000 square miles of fresh water in Canada should be served by a single fresh-water laboratory, that on the Georgian bay? If our fresh-water fisheries are to be conserved and if we are to make our fresh waters more productive, it will be necessary to have more fresh-water biological laboratories or stations established where those problems relating to the bionomics of our fresh-water fishes may be studied. At the recent annual meeting of the Entomological Society of Ontario held at Ottawa I moved the following resolution which was unanimously adopted by the Society:

" THAT in view of the decrease in the supply of the fresh-water fisheries of Canada, the attention of the Commission of Conservation be called to the important fact, which is being overlooked in the endeavours to replenish depleted waters by re-stocking and to stock new waters, that, as the chief food of many of our important fresh-water fishes consists of larvæ and adult insects, a study should be made of the available or possible food supplies in the way of insect life before attempts are made at replenishing or stocking waters; otherwise by stocking waters in which the food supply is not suitable or cannot be made suitable, large sums of money and considerable time and energy will be uselessly expended owing to fish being planted where the food is either insufficient or of the wrong character, as the conservation of our fresh-water fishes cannot be carried out with the greatest success until

more knowledge is available as to their feeding habits and requirements, and the insect or other fauna and available food supplies of the waters in which they are living or which it is desirable to stock with fish; and that a copy of this resolution be forwarded to the Secretary of the Commission of Conservation."

Our present inactivity in this regard is due chiefly to two causes: first, a general lack of appreciation of the importance of the problem which I am discussing, and, secondly, the difficulty of obtaining investigators. Both of these I am convinced will be remedied by time, and at the present time we must have our sight sufficiently well adjusted to take a long-distance view of the needs in these directions. With these problems confronting us, we are compelled to look ahead and to point out, possibly in advance of our ability to undertake them, the necessity and importance of attacking problems which the advance of time and increase of population aggravates. This is a matter which affects the home seeker whom we are attracting to our shores in thousands and the people who live in cities. And how do we know whether it may not affect those causes which contribute to clear thinking on the part of the people of this young country? Fish as is well known contains such a constituent as phosphorus, which is an important constituent of brain matter and nervous tissue. This Commission and your Committee on Fisheries can do much, and in my opinion, more than any other body, to bring about the materialization of the ideas which I have briefly outlined. I commend them to your most thoughtful consideration in the firm belief that their ultimate adoption would prove of incalculable benefit to the people of Canada.